705 St. Paul Street
Rochester, New York 14605
Telephone: (585) 248-4100
Fax: (585) 248-4111
E-mail: gratings@newport.com
Web Site: http://www.gratinglab.com

Technical Notes

Technical Note 6
ECHELLE GRATINGS

ECHELLE GRATINGS

An echelle grating differs from a conventional grating (called an echelette) in many ways. An echelle is coarse (i.e., it has fewer grooves per millimeter than an echelette) and is used at high angles in high diffraction orders. The virtue of an echelle lies in its high efficiency and low polarization effects over large spectral intervals. Together with high dispersion, this leads to compact, high-resolution instruments.

An important limitation of echelles is that the orders overlap unless separated optically, for instance by a cross-dispersing element. A prism or echelette grating is often used for this purpose. This combination leads to an output format well matched to CCD arrays.

Figure 1 – Echelle grating geometry (Littrow).

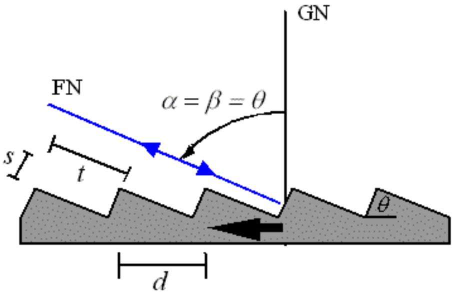

Figure 1 shows the geometry of an echelle grating. For a conventional (echelette) grating, the longer groove facet (of length *t*) would face toward the incident and diffracted light; for an echelle, the shorter, steeper groove facet (of length *s*) is facing toward the light. Echelles are often used in or near the Littrow configuration (shown), in which the angle of incidence α equals the angle of diffraction β, though they have been used with as much as $\alpha - \beta = 40°$ between the beams.

APPLICATIONS OF ECHELLES

Echelles are most often used in applications where their high dispersion and resolution are important. This covers atomic spectrometry, laser tuning, and astronomy. Since they operate in many diffraction orders, echelles are capable of wide wavelength coverage, being used from 100 nm into the infrared. Echelles are found on several space spectrographs, including the Hubble Space Telescope.

TYPES OF ECHELLES

The two design parameters that define an echelle grating are its groove frequency G (= $1/d$) and its blaze angle θ (see Figure 1). Echelles presently range in groove frequency from 23 to 316 mm^{-1}. Blaze angles include, but are not limited to, 32°, 44°, 63.4°, 71.5°, 76° and 79°; the last four are chosen because their tangents are 2, 3, 4 and 5. [Often echelles are specified by their "R number", which equals this tangent; for example, an R4 echelle in one with blaze angle arctan(4) = 76°.] Angles above 63.4° have found their applications chiefly since the mid 1980s.

SIZES OF ECHELLES

Commonly used sizes vary from 50 by 100 mm to 308 by 408 mm, where the shorter number specifies the groove length and the longer number the ruled width. Smaller and intermediate sizes are also available. Because dispersion is high, it is important to maintain constant groove spacing, which is why echelles are often replicated onto low thermal expansion materials.

A recent development has been to make echelles larger than the standard 408 mm ruled width limit, in order to satisfy the needs of large astronomical spectrographs. This can be accomplished by the precise double replication of a single ruling onto a larger substrate; the resulting grating is called a mosaic.

COATINGS

The majority of echelles are supplied with aluminum surfaces. For applications below 200 nm, it is necessary to overcoat echelles with a thin layer of magnesium fluoride (MgF_2) to prevent the oxidation of the aluminum (which decreases ultraviolet efficiency).

EFFICIENCY BEHAVIOR

The high efficiency of echelles is maintained near the Littrow angle. This means moving progressively through a series of diffraction orders to cover the entire spectral range. Within each order, the efficiency will be maximum at the middle (typically reaching 50 to 75%), but dropping to about one-half these values at the crossover points. Interorder efficiency behavior closely follows scalar theory; however, when the diffraction order of use is low, or when the diffraction angles are high, the detailed efficiency properties are governed by electromagnetic (vector) theory. Accurate theoretical formulation of this case is a recent achievement.

TESTING ECHELLES

Echelle gratings are subject to careful testing. Resolution close to the theoretical limit can be verified by interferometric and Foucault wavefront tests, and also by observation of the hyperfine spectra of mercury. Efficiency is determined with mercury and laser light sources, to ensure narrow spectral line widths. Exact blaze angles are derived by one of several methods.

ORDERING INFORMATION

The *Diffraction Grating Catalog* lists a wide variety of echelle gratings. Please contact us for price quotations. Echelles can also be ruled to specifications if no catalog grating is appropriate.

FOR FURTHER INFORMATION

For additional information, please contact us.

SOME TECHNICAL REFERENCES

- G. Harrison, "Design of echelle gratings and spectrographs," *J. Opt. Soc. Am.* **39**, 522-528 (1949).
- D. Schroeder, Astronomical Optics, Academic Press (New York, 1987), ch. 15.
- R. Tousey, "The Extreme Ultraviolet – past and future," *Appl. Optics* **1**, 679-680 (1977).
- G. Harrison, E. Loewen and R. Wiley, "Echelle testing and improvement," *Appl. Optics* **15**, 917-976 (1976).
- P. Keliher, "Application of echelle spectrometer to atomic spectroscopy," *R&D Magazine* **27**, 26-28 (1976).
- S. Engman and P. Lindblom, "MEGA Spectrometer," *Appl. Optics* **23**, 3341-3348 (1984).
- E. Loewen, D. Maystre, E. Popov and L. Tsonev, "Echelles: scalar, electromagnetic and real groove properties," *Appl. Optics* **34**, 1707-1727 (1995).
- E. Loewen et al., "Diffraction efficiency of echelles working in extremely high orders," *Applied Optics* **35**, 1700-1704 (1996).
- E. Popov et al., "Integral method for echelles covered with lossless or absorbing thin dielectric layers," *Applied Optics* **38**, 47-55 (1999).
- E. Loewen and E. Popov, *Diffraction Gratings and Applications*, Marcel Dekker, Inc. (1997); ISBN 0-8247-9923-2

back to top

E-mail: gratings@newport.com,
Web Site: http://www.gratinglab.com